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Influence of INM on yield and nutrient uptake in sorghum-barley cropping sequence

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Abstract
A field experiment was conducted during the *Kharif* and *Rabi* season of the year 2010-2011 and 2011-2012 at Rajasthan College of Agriculture, Udaipur, to study the influence of integrated nutrient management on yield and nutrient uptake in sorghum-barley sequence. Two levels of farmyard manure (FYM) (0 and 10 tonnes/ha), four fertility levels based on soil test recommendation (0%, 50%, 75% and 100% NPK) and four biofertilizers (No inoculation, *Azotobacter*, phosphate solubilizing bacteria (PSB) and dual inoculation of *Azotobacter* + PSB) were compared. Application of FYM 10t/ha significantly increased grain (28.16 & 16.40%) and stover (12.11 & 19.93%) yields of both the crops alongwith nutrient uptake (NPK) over the control. The residual effect of FYM 10t/ha on succeeding crop barley and also significantly increasing grain and straw yield was 16.40% & 19.93% over control. The Addition of FYM 10 tonnes/ha residual effect of FYM on sequence crop were significantly improvement of the yields and nutrient uptake. Significant enhancement in grain (27.87 and 20.09%) and stover (12.46 and 15.15%) yields were observed sorghum-barley sequences with the application Azotobacter + PSB over no inoculation. Application of 100 % NPK increased grain (45.14 and 23.43%) and stover (12.26 and 13.19%) yields both the crops over the control. Improvement in N, P and K uptake in sorghum (41.07, 29.13 and 21.10%) alongwith barley (31.98, 25.95 and 23.23%) were also observed with application of 100% NPK over control

Keywords: FYM, biofertilizer, sorghum, barley, yields, nutrient uptake

Introduction
In India, the area under sorghum is approximately 5.79 million ha with an annual production of about 5.45 million tonnes and an average productivity of 957 kg/ha (DAC, 2014) [3]. Barley (*Hordeum vulgare* L.) is another important cereal crop of ranking just next to the rice, wheat, sorghum and maize both in terms of acreage and grain production. In India the area under barley cultivation was approximately 0.67 million hectares with production of about 1.61 million tonnes (DAC, 2014) [3]. Since the possibility of horizontal expansion or putting more area under cultivation is difficult, future augmentation in yield should have to be harnessed vertically through increase in productivity by judicious management of all input especially nutrients. There is a need to develop more efficient, economic and integrated system of nutrient management. Although the balanced use of N, P and K fertilizers could maintain productivity, in practices it has shown a declining trend, which has been attributed to the continuous and intensive use of chemical fertilizers. The deteriorating productivity found to be associated with deterioration of soil physical and biological qualities besides imbalance in micronutrients In Zone IVA (Sub-humid Southern Plain and Aravali Hills) of Rajasthan, a fertilizer dose of 80 kg N + 40 kg P_2O_5 + 40 kg K_2O/ha has been recommended for the cultivation of sorghum but still the efficiency and productivity is low.

The INM, however, helps in maintaining the productivity of soil and improves fertilizer-use efficiency. It economizes the use of chemical fertilizers by influencing the yield of *kharif* crop (Bejbaruha *et al.*, 2009) [2]. Besides nutrients availability, FYM also improves soil physical characteristics such as structures, porosity and water-holding capacity through increased organic matter content of soil. FYM when applied in conjunction with biofertilizers, supplies energy to beneficial microorganisms including *Azotobacter* and PSB. Integrated plant nutrition involve judicious and integrated use of chemical/ synthetic sources of nutrients along with biofertilizers in addition to nutrient recycling through use of organic manures, green manuring and biodegradable wastes etc. Biofertilizers offer a low cost, low capital intensive and ecofriendly route to boost the farm productivity depending upon their activity of mobilizing different nutrients. Use of biofertilizer in crop not only fixes the biological nitrogen but also solubilizes the insoluble phosphates in soil and thus improves fertilizers-use efficiency (Gogoi 2008) [6]. These microorganisms play an important role in increasing the availability of N, P and K. Keeping this in view, present investigation was undertaken to find out effect INM on productivity and nutrient uptake in sorghum-barley.

Materials and Methods

A field experiment was carried out during *Kharif* and *Rabi* season of the year 2010-2011 and 2011-2012 at Rajasthan College of Agriculture, Udaipur. The site was situated at 24º.35' N, 74º.42' E longitude and an altitude of 579.5 m above mean sea-level. The region falls under agro-climatic zone IVA of Rajasthan. The soil was clay loam, medium in organic carbon (0.68 and 0.70%), low in available nitrogen (266.80 and 270.20 kg/ha) and medium in phosphorus (19.80 and 22.50 kg/ha) and high in potassium (358.50 and 365.80 kg/ha), with pH 7.98 and 8.10 in 2010 and 2011 respectively. The treatments consisted of two levels of farmyard (0 and 10 tonnes FYM/ha), four fertility levels (0%, 50%, 75% and 100% NPK) based on soil test recommendation (STR) and four inoculations (no inoculation, *Azotobacter*, PSB and dual inoculation of *Azotobacter* PSB). These treatments were evaluated in split-plot design, allocating organic manure and fertilizers in main plots and biofertilizers in subplots and replicated three times. Sorghum variety CSV 23 was sown in furrows at 45 cm row spacing using a seed rate of 10 kg/ha. Barley variety RD 2052 was sown at 22.5 cm row spacing to a depth of 5 cm. Application of fertilizers (51.98 kg N, 45.54 kg P_2O_5 and 15.60 kg K_2O/ha) to sorghum and (40.48 kg N, 25.03 kg P_2O_5, 10.20 kg K_2O) to barley based on soil test recommended doses was applied as per treatment. Half dose of N and full dose of P and K applied basal at the time of sowing and remaining half dose of N at 30 days after sowing. Seeds were uniformly coated with *Azotobacter* inoculums using 500 g/ha and Bacillus megatherium var. phosphaticum @ 5 g/kg seed as per the treatments. The crops were harvested at maturity and plant samples were taken. Nutrient content in plant sample analyzed as per procedure suggested by Snell and Snell (1959) [14] and Jackson (1967) [7]. The results were analyzed using standard statistical procedure given by Panse and Sukhatme (2000) [11].

Results and Discussion

Effect of farmyard manure

As the crop was grown under identical management conditions and input level the observed variation in production of sorghum-barley grain yield between the years seems to be due to variation in climatic conditions which prevailed during various stages of crop growth. The profound influence of environmental factors affected the crop productivity despite consistency of other input parameters and practices of crop husbandry.

Application of organic manure in the form of FYM @ 10 t ha^{-1} significantly increased the grain yield of sorghum and barley by 28.16 and 16.40 per cent, respectively over control (Tables 1 & 2) which could be attributed to the release of macro and micro nutrients during the course of microbial decomposition. The increase in yields might be owing to beneficial effect of FYM in improving the soil environment resulting in better absorption of moisture, nutrient and thus resulting in higher yields. Khaswan *et al.* (2012) [9], also reported similar finding in terms of crop yield performance. The favorable effects of organic material are known to fade with time, as organic contents undergo decomposition depending on temperature and moisture, leading to less and less residual effects. Consequently the first crop gets maximum benefit and the following crop is benefited to a lesser extent which has also been reflected in this study. The barley yield increased from 4.33 to 5.04 tonnes/ha due to residual effect of FYM applied to the previous crop sorghum. Patidar and Mali (2002) [12] and Bejbaruha *et al.* (2009) [2] also reported that application of FYM to *kharif* crop gave significant residual effect on the grain yield of succeeding barley crop.

Addition of 10 t FYM ha^{-1} increased the uptake of N, P and K by sorghum to barley (Table 1 & 2). The sorghum crop with application of under the influence of 10 t FYM accumulated higher quantum of N, P and K uptake by 22.41, 20.04 and 15.74 per cent, and succeeding crop of barley by 25.35, 21.11 and 22.66 per cent, respectively over control. The significant influence of organic manure (FYM) might be due to enhanced growth characters, increasing rate of N, P and K nutrients and availability for longer period from FYM which synchronized the crop demand. Application of organic manure not only increased the uptake of nutrients through mineralization but also reduce the losses of N which otherwise occurs through leaching and/or volatilization (Dadheech and Somani, 2007) [4]. A significant improvement in uptake of N, P and K as a consequence of organic manuring have also been reported by Meena *et al.* (2010) [10] and Jat *et al.* (2013) [8].

Effect of fertility level

Results showed that yield of both the crops *i. e*. sorghum as well as barley increased significantly with increasing levels of NPK (STR) from no application to 100% application. The grain increased from 2.88 to 4.18 tonnes/ha in sorghum and from 4.14 to 5.11 tonnes/ha in barley without and with 100% NPK application, based on STR. However, the maximum yield of both crops was 4.18 & 5.11 tonnes/ha obtained with application of 100 % NPK. Application of 100 % NPK increased grain (45.14 and 23.43%) and stover (12.26 and 13.19%) yield of both the crops over the control. Such improvement in yield with increasing levels of fertilizer application was supported by the findings of Singh *et al.* (2011) [13]. It is essential that fertilizers must be applied in right quantity, at right time and place, from right source and in right combination in order to get maximum benefit from fertilizers. The present results are in close agreement with the findings of Jat *et al.* (2013) [8]

Improvement in N, P and K uptake in sorghum (41.07, 29.13 and 21.10%) alongwith barley (31.98, 25.95 and 23.23%) were also recorded with 100% NPK over control. The uptake of N, P and K increased with progressive increase in the supply of NPK to the crops because of higher availability of these nutrients resulting in higher biomass yield. The impact of higher uptake of plant nutrients under these treatments has been reflected in the growth and yield performance of the crop (Bejbaruha *et al.* 2009 and Faujdar, 2011) [2, 5].

Effect of biofertilizers

The application of biofertilizers significantly increased the yield of sorghum as well as of barley (Tables 1 & 2). The magnitude of increase in grain and stover yield of sorghum was to the extent of 27.87 and 12.46 per cent with the dual inoculation of biofertilizers (*Azotobacter* + PSB) over no inoculation. Similarly, the magnitude of increase in grain, and straw yield of barley was 20.09 and 15.15 per cent with the application of biofertilizers inoculation over no inoculation. Similar findings had earlier been reported by Dadheech and Somani (2007) [4] and Jat *et al.* (2013) [8]. Application of biofertilizers significantly increased the uptake of N, P and K by sorghum (1 & 2) and barley (Table 1 & 2), whether used singly or in combination. The sorghum crop under influence of dual inoculation (*Azotobacter* + PSB) accumulated higher quantum of nutrients (N, P and K uptake) by 30.16, 25.54 and 16.69 per cent, respectively over that observed under control. Azotobacter also proveded significantly better than PSB similarly, the barley crop under the influence of biofertilizers (*Azotobacter* + PSB) also accumulated higher quantum of nutrients N, P and K uptake by 35.57, 26.04 and 19.97 per cent, respectively over control. Biofertilizers, the microbial inoculants which bring about fixation of atmospheric nitrogen either in free living N_2 fixer in the rhizosphere (*Azotobacter*, PSB) or transform native unavailable phosphorus into plant utilizable or improving germination, plant growth, plant stands and vegetative growth of plant, are low cost eco-friendly input for farmers. Biofertilizer has been identified as a good supplement to chemical fertilizer to increase soil fertility and crop production in sustainable farming. The use of bio-fertilizer results in the highest biomass and increased the nutrient uptake by plants (Singh *et al.* 2011) [13].

Table 1: Effect of FYM, fertility levels and biofertilizers on yields and nutrient uptake of sorghum (mean data of two years)

Treatments	Yields (tonnes/ha)		N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)
	Grain	Stover			
FYM (tonnes/ha)					
0	3.16	13.29	115.22	37.13	227.63
10	4.05	14.90	141.04	44.57	263.47
CD (p= 0.05)	0.12	0.25	2.46	0.79	4.42
Fertility levels (based on STR)					
0% NPK	2.88	13.13	103.70	35.09	218.98
50% NPK	3.36	13.97	123.66	39.17	240.06
75% NPK	4.00	14.56	138.87	43.84	257.96
100% NPK	4.18	14.74	146.29	45.31	265.19
CD (p = 0.05)	0.17	0.35	3.48	1.12	6.26
Biofertilizers					
No inoculation	3.05	13.25	108.48	35.51	225.71
Azotobacter	3.83	14.30	134.22	42.03	250.14
PSB	3.65	13.94	128.62	41.30	242.97
Azotobacter + PSB	3.90	14.90	141.20	44.58	263.38
CD (p = 0.05)	0.16	0.28	2.48	0.77	4.90

Table 2: Effect of residual FYM, fertility levels and biofertilizers on yields and nutrient uptake of barley

Treatments	Yield (tonnes/ha)		N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)
	Grain	Straw			
FYM (tonnes/ha)					
0	4.33	5.82	98.43	27.09	117.20
10	5.04	6.98	123.38	32.81	143.76
CD (p = 0.05)	0.13	0.13	2.53	0.69	2.67
Fertility levels(based on STR)					
0% NPK	4.14	5.99	94.49	26.24	116.64
50% NPK	4.60	6.21	107.60	29.16	125.76
75% NPK	4.90	6.61	116.83	31.34	135.79
100% NPK	5.11	6.78	124.71	33.05	143.73
CD (p = 0.05)	0.19	0.19	3.58	0.99	3.78
Biofertilizers					
No inoculation	4.23	5.94	94.06	26.15	118.42
Azotobacter	4.78	6.50	115.18	30.64	132.78
PSB	4.66	6.30	109.70	30.05	128.65
Azotobacter + PSB	5.08	6.84	124.70	32.96	142.07
CD (p = 0.05)	0.16	0.12	3.25	0.76	2.81

Interaction

Fym x npk

Application of FYM @ 10 tonnes/ha with 100% NPK resulted in maximum NPK uptake of sorghum, being at par with FYM and 75% NPK (Table 3 & 4). Improvement in N, P and K uptake in sorghum (76.53, 59.86 & 45.82 %) alongwith barley (71.46, 69.70 & 55.08 %) were also noticed with 100% NPK over control. This indicates that use of FYM in combination with fertility levels has beneficial effect in improving the crop yield. The beneficial response of FYM to yield might also be attributed to the better availability of sufficient amounts of plant nutrients throughout the growth period and especially at critical growth period of crops which has resulted in better plant vigour and superior yield attributes (Bayu *et al.*, 2006) [1]. The uptake by both the crops was higher in NPK + FYM treatments indicating better availability of nutrients through complementary residual effect on succeeding crop.

Table 3: Interaction effect of FYM and NPK on total NPK uptake (kg ha^{-1}) by sorghum (mean data of 2 years)

Treatments	NPK Level (% STR)											
	N				P				K			
	0	50	75	100	0	50	75	100	0	50	75	100
FYM (tonnes/ha)												
0	90.78	111.43	126.32	132.34	30.17	35.49	40.49	42.38	189.48	222.72	244.25	254.08
10	116.62	135.89	151.42	160.25	40.02	42.86	47.20	48.23	248.49	257.41	271.67	276.30
CD (P=0.05)	4.92				1.58				8.85			

Table 4: Interaction effect of FYM and NPK on total NPK uptake (kg ha^{-1}) by barley (mean data of 2 years)

Treatments	NPK Level (% STR)											
	N				P				K			
	0	50	75	100	0	50	75	100	0	50	75	100
FYM (tonnes/ ha)												
0	85.07	99.69	105.42	103.56	19.11	22.88	24.35	24.25	103.18	114.32	123.86	127.46
10	103.92	115.51	128.24	145.86	23.51	25.48	28.16	32.43	130.09	137.20	147.73	160.01
CD (P=0.05)	5.06				1.64				5.35			

FYM X Biofertilizers

Inoculation with *Azotobacter* and PSB alone or in combination significantly increased NPK uptake by sorghum both in absence and presence of FYM @ 10 t ha^{-1} (Table 5 & 6). The highest NPK uptake was recorded under *Azotobacter* + PSB alongwith 10 t FYM ha^{-1} treatment and the magnitude of increase in uptake (N, P & K) was to the extent of 61.97, 52.43 and 34.72 per cent, respectively over control. NPK uptake by barley increased significantly when inoculated with *Azotobacter* and PSB in presence of residual FYM @10 t ha^{-1} with a magnitude of 74.35, 58.72 and 52.41 per cent, respectively over control. Similar findings have been also reported by Jat *et al.* (2013) [8].

The beneficial interaction of FYM and inoculants could be attributed to heterotrophic nature of organisms used for inoculation which helped in their survival and multiplication. The improved physico-chemical properties with the FYM incorporation and the nutrients supplied or its transformation had positive effect on decomposed organism as well as indirectly plant growth. Similar findings have been also reported by Faujdar, (2011) [5].

Table 5: Interaction effect of FYM and biofertilizers on total NPK uptake (kg ha^{-1}) by sorghum (mean data of 2 years)

Treatments	Biofertilizers											
	N				P				K			
	B_1	B_2	B_3	B_4	B_1	B_2	B_3	B_4	B_1	B_2	B_3	B_4
FYM (tonnes/ha)												
0	99.16	121.93	117.99	121.78	32.35	38.35	37.99	39.84	209.00	230.06	226.28	245.19
10	117.80	146.51	139.25	160.61	38.68	45.70	44.60	49.31	242.41	270.23	259.67	281.56
CD (P=0.05)	3.51				1.09				6.92			

Table 6: Interaction effect of FYM and biofertilizers on total NPK uptake (kg ha^{-1}) by barley (mean data of 2 years)

Treatments	Biofertilizers											
	N				P				K			
	B_1	B_2	B_3	B_4	B_1	B_2	B_3	B_4	B_1	B_2	B_3	B_4
FYM (tonnes/ha)												
0	81.34	106.94	97.88	107.57	23.04	28.72	27.26	29.35	102.58	121.93	116.50	127.80
10	106.78	123.41	121.52	141.82	29.26	32.56	32.84	36.57	134.26	143.62	140.80	156.34
CD (P=0.05)	4.59				1.07				3.98			

Conclusions

The study investigation it can be concluded that beneficial effect of INM is visualized in first crop and it residual effect of FYM in second crop of the sequence. The application of FYM along with 100% NPK based on STR and coinoculation of *Azotobacter* + PSB improved yield and nutrient uptake in sorghum-barley cropping sequences under the prevailing agro-climatic condition.

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